# TIDAL ENERGY SITE RESOURCE ASSESSMENT:
## TECHNICAL SPECIFICATIONS, BEST PRACTICES AND CASE STUDIES


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## I. Introduction

The development of tidal energy site resource assessment technical specifications and best practices is critical to support the growth of this marine renewable energy industry. These methods need to be based on best available measurement technologies and deployment methods, while minimizing overall cost. As with the wind industry, the adoption of best practices has numerous benefits for the tidal energy industry, including a reduction of costs by adopting a systematic framework for resource assessment across multiple sites, and the collection of data using uniform documented methods that allows comparison between different sites. Assuming data is collected in a consistent fashion, we can develop tidal energy site classes that map to standard TEC designs, similar to the wind industry.

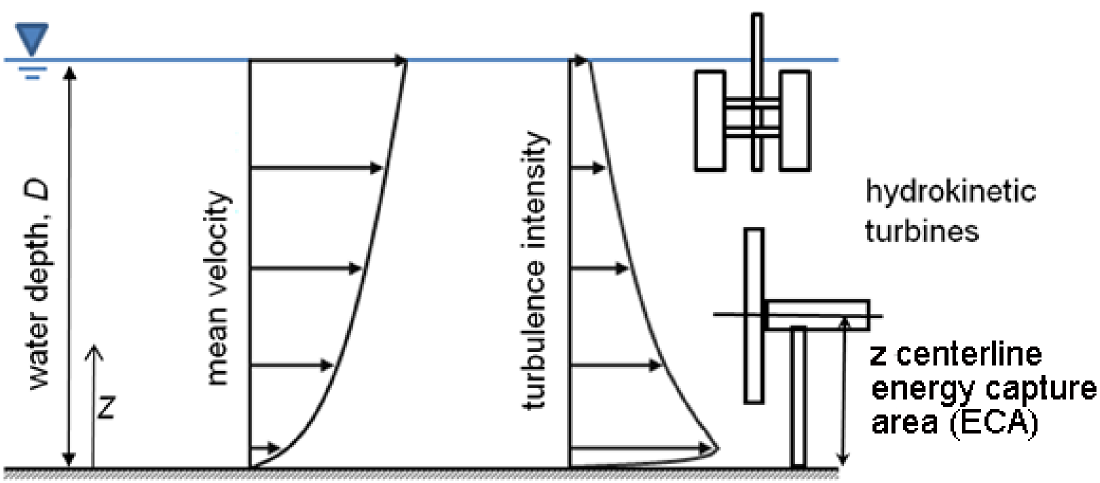


Fig. 1 Typical distributions of velocity and turbulence and sketch of horizontal-axis and cross-flow hydrokinetic turbines. Modified from Neary and Sale (2010).

As illustrated in Fig. 1, the siting and design of a tidal energy converter (TEC) requires characterization of the spatio-temporal variation of the current velocity and turbulence acting on the energy capture area (ECA) of the TEC in order to: determine the hydrodynamic forces and available power estimates over a representative period of record, to design the structural loading and power capacity of the TEC, and to inform investment decisions and project financing.

We present two related efforts to develop consistent methods for tidal energy site resource assessment: (1) The International Electro-technical Commission (IEC) technical specification (TS) for tidal energy resource assessment and characterization, and (2) The best practices manual (BPM) for tidal site energy resource development (Neary et al. 2011). The IEC technical specification, currently in review as a committee draft, is focused solely on methods to estimate the tidal energy resource at regional, channel reach, and TEC array site scales. The BPM, published in September 2011, is generally broader in scope than the IEC TS, including methods for baseline environmental monitoring as well as resource assessment, but it is only focused on array site and machine scale resource assessments. We present examples that illustrate the application of these methods in Puget Sound, Cook Inlet, and at Verdant Power's Roosevelt Island tidal energy (RITE) site.

## II. Best Practices Manual

The Best Practices Manual (BPM) reviews existing data collection techniques and protocols for characterizing flows in rivers, as well as tidal channels, and refines these methods to address the needs of the marine and hydrokinetic industry. The report provides an overview of the hydrodynamics of river and tidal channels, and the working principles of modern acoustic instrumentation, including best practices in remote sensing methods that can be applied site resource assessment. Emphasis is placed upon measurements with acoustic Doppler velocimeter (ADV) and acoustic-Doppler current profiler (ADCP) instruments, as these represent the best available instruments for velocity and turbulence measurements. The manual incorporates the best practices found in the literature, including the parameters to be measured, the instruments to be deployed, the instrument deployment techniques, and data post-processing methods. The data collected from this procedure aims to inform the hydro-mechanical design of MHK systems with respect to energy generation and structural loading, as well as provide reference hydrodynamics for environmental impact studies. The standard metrics and protocols defined in this manual can be utilized to guide field experiments with MHK systems.

## III. IEC Technical Specification

The goal of the IEC Technical Specification is for tidal resource assessment only. It provides a standardized methodology for developing annualized probability distributions of current velocity, which defines the tidal energy resource in the IEC TS, as an input to the standard for tidal performance assessment. The tidal current resource, as defined in the TS, is limited to the current velocity probability distribution sufficient for computing the annual energy production (AEP) by a single TEC or an array of them. The IEC TS reviews tidal energy resource assessment at three different stages: regional, estuary and development site. Emphasis is placed upon development and validation of numerical model for projects of greater than 10 MW capacity. Requirements for recommended numerical model and physical data for each stages, as well as analysis and presentation of the results, are outlined. The IEC TS incorporates some descriptions on different data types that include bathymetry, tidal characteristics, meteorological data, wave climate, and the methods to obtain them. In summary, the IEC TS is document with narrower objectives than the BPM and emphasizes modeling over measurement.

## IV. Best Management Practice Example – RITE Site, Verdant Power

Although the site resource assessment for Verdant Power's Roosevelt Island tidal energy (RITE) site was determined using ADCP measurements, ADV measurements at the hub-height of the planned turbine location were also collected following best management practices described in Neary et al. (2011). This site resource assessment therefore represents an example of a high fidelity site resource assessment at the machine scale with an emphasis on measurements instead of modeling at the scale of the TEC. The frequency of occurrence of the instantaneous horizontal current at this location was examined by constructing the frequency and cumulative frequency histograms shown in Fig. 2, which shows available power occurred 74% of the time, when the current is above the turbine cut-in speed and below the turbine cut-out speed.

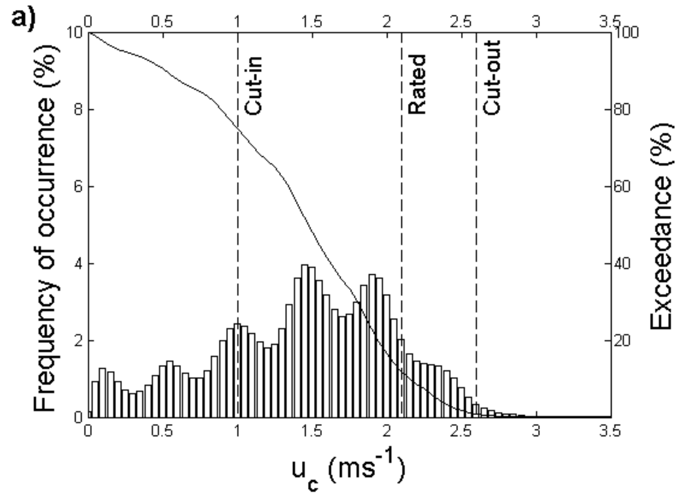


Fig. 2 Frequency histogram (bar) and cumulative frequency histogram (line) of horizontal current at the RITE site.

## V. IEC Technical Specification Example – Cook Inlet, Alaska

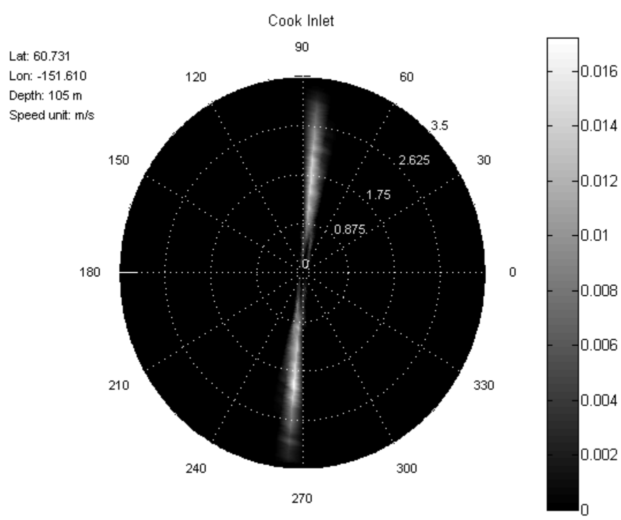


Fig. 3 Joint velocity and direction probability distribution, a location in Cook Inlet, Alaska. Calculated from the US tidal energy database http:\\www.tidalstreampower.gatech.edu, Defne et al. (2012).

The main model output described in the IEC TS is the percentage of time, $f(U_i, \theta_k)$, that the current velocity falls within each specified bin for velocity and direction. It is recommended that a table be provided with the results of the histogram analysis, and that the computed histograms should be used to plot the joint current velocity direction distributions as shown in Fig. 3. The velocity distribution at the site location(s) is the sum of the probabilities across all directions.

## VI. IEC Technical Specification Example – Puget Sound, Washington

A challenge to use of models for predicting annual power generation is the need to validate them against measurements. In general, validation measurements are sparse, but, in the case of northern Admiralty Inlet, Puget Sound, Washington, a high concentration of ADCPs has been deployed since 2009 (Polagye and Thomson, in press). The comparison to a high resolution (65 m horizontal resolution) numerical model (Thyng, 2012) in Fig. 4 shows that the model effectively reproduces spatial trends in kinetic power density, but somewhat underpredicts the current intensity, particularly near the headland. The spatial variations observed by both the model and measurements demonstrate both the need for and challenges associated with high resolution numerical modeling for resource assessment in areas with complicated bathymetry.

## VII. Conclusions

Although best practices for tidal energy site resource assessments have been put forth (e.g. Neary et al. 2011), including the instruments needed for collecting current velocity and turbulence measurements, deployment strategies for these instruments, and methods for post-processing and analyzing raw instrument measurements, such practices have yet to be universally adopted. The growing number of tidal energy site resource assessment studies, like those presented here, is providing invaluable experience that will help formulate and improve tidal energy site resource assessment practices, while also improving our knowledge of the range of hydrodynamic conditions at tidal energy sites where current velocities are sufficiently high to justify financing commercial scale projects.

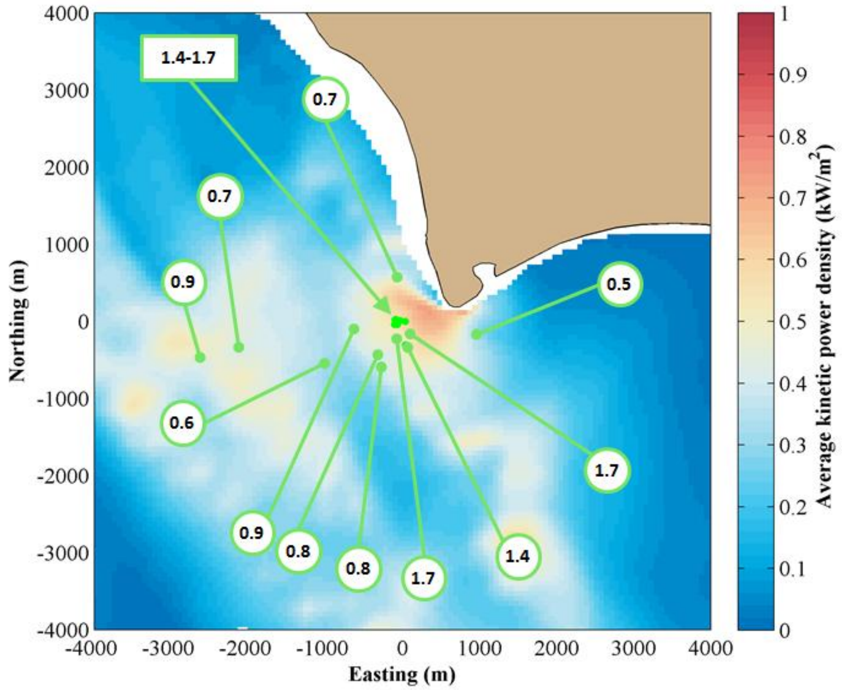


Fig. 4 – Comparison between time-average kinetic power density at 10 m above seabed from numerical modeling (color, Thyng, 2012) and measurements (labeled points, Polagye and Thomson, in press).

## VIII. References

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